DRAFT SAMPLING AND ANALYSIS PLAN
Badwater Creek
2019-2020

Wyoming Department of Environmental Quality
Water Quality Division
Watershed Protection Program

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Signature Approval Sheet

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Background

Badwater Creek (1008000601, 1008000604, and 1008000603 HUC10s) and Alkali Creek (1008000602 HUC10) watersheds are located in northeast Fremont County and northwest Natrona County, Wyoming, and comprise approximately 3% of the Boysen Reservoir watershed (Figure 1). As identified in the Wyoming Surface Water Classification List, Badwater Creek is Class 2AB stream and designated for drinking water, cold water game fish, nongame fish, aquatic life other than fish, recreation, industry, wildlife, agriculture, and scenic value uses. Alkali Creek is Class 3B and designated for aquatic life other than fish, recreation, industry, wildlife, agriculture and scenic value uses. Chapter 1 of the Water Quality Rules and Regulations, Wyoming Surface Water Quality Standards (hereafter Chapter 1), contain a number of water quality criteria for Class 2AB designated uses, including chloride criteria (230 milligrams per liter (mg/L) chronic and 860 mg/L acute) to protect game and nongame fisheries. Since Alkali Creek is Class 3B, most of the water quality criteria are the same as those that apply to Badwater Creek, with the exception of human health criteria for drinking water and fish consumption as well as aquatic life criteria for temperature, ammonia, and chloride. In the case of aquatic life criteria for temperature, ammonia, and chloride, narrative rather than numeric criteria apply to Alkali Creek.

Produced water from the Moneta Divide gas field, previously known as Frenchie Draw, is discharged to Alkali Creek via a series of outfalls at approximately 25,000 barrels per day or 1.2 cubic feet per second (cfs). Water from Alkali Creek then flows into Badwater Creek which is a tributary to Boysen Reservoir. The oil field was originally developed by Exxon in the 1960's and has since traded hands to Tom Brown, Inc., then Encana Oil and Gas, and in 2015 to the current operator, Aethon Energy (Aethon). The original permits for discharges of produced water were issued by the United States Army Corps of Engineers and transferred to the United States Environmental Protection Agency (USEPA) in 1972 upon adoption of the federal Clean Water Act. Regulatory responsibility transferred to the Wyoming Department of Environmental Quality (WDEQ) in January 1975 when USEPA approved the WDEQ National Pollutant Discharge Elimination Systems (NPDES) program, known in the State of Wyoming as the Wyoming Pollutant Discharge Elimination System (WYPDES), and suspended the issuance of NPDES permits by USEPA.

Aethon is interested in increasing production from the oil and gas field and updating their WYPDES permit to accommodate the increase in produced water. As a result, WDEQ is evaluating the surface water quality standards (i.e., antidegradation requirements, designated uses, and water quality criteria) associated with Badwater Creek, which is a downstream receiving water. This evaluation will determine whether the existing water quality standards, including numeric aquatic life criteria for chloride, are appropriate. Chemical, physical, and biological data are therefore needed to characterize Badwater Creek above and below its confluence with Alkali Creek and, if appropriate, develop scientifically defensible water quality criteria protective of designated uses and/or modify the designated uses for Badwater Creek.

Objectives

In collaboration with Aethon, WDEQ will sample Badwater, Alkali, Dry, and Bridger Creeks throughout 2019 and into 2020 in order to:

1) Determine the aquatic communities present in Badwater Creek and the chloride criteria necessary to protect those communities. Criteria may be based on ambient concentrations of chloride, natural concentrations of chloride, and/or the toxicity of chloride to aquatic organisms that occur or are expected to occur in Badwater Creek; and
2) Collect sufficient information to evaluate whether the currently assigned designated uses and water quality criteria are appropriate for Badwater Creek, and in circumstances where the

designated uses and/or water quality criteria are not appropriate, to support modifications of the uses and/or criteria.

This study will be conducted at 13 sites to represent chemical, physical, and biological conditions in the Badwater Creek watershed: 10 sites on Badwater Creek and one site at each terminus of the Dry Creek, Bridger Creek and Alkali Creek tributaries (Figure 1). Sites on Dry Creek, Bridger Creek, and Badwater Creek upstream of Alkali Creek are intended to help characterize the chemical, physical, and biological conditions, with specific attention to chloride concentrations and temperature, that do not receive oil and gas effluent from the Moneta Divide. Due to its location upstream of towns and much of the irrigated agriculture, the uppermost site on Badwater Creek is intended to represent aquatic communities and water quality with minimal anthropogenic influences. The sites on Badwater Creek downstream of Alkali Creek are intended to help characterize the existing chemical, physical, and biological conditions of Badwater Creek. An additional site upstream of the outfalls on Alkali Creek may be added to determine conditions on Alkali Creek with minimal anthropogenic influences. Further description of each site can be found in the Sampling section of this Sampling and Analysis Plan (SAP).

Credible Data and QAPP

All data are collected in accordance with the credible data law specified in the Wyoming Environmental Quality Act § 35-11-302 (b)(i) and (b)(ii) and detailed in Chapter 1, Section 35 of the Wyoming Water Quality Rules and Regulations. This SAP is covered by the WDEQ Water Quality Division (WQD), Watershed Protection Program Monitoring Quality Assurance Project Plan (QAPP) (WDEQ/WQD 2018a).

Corrective Actions

Project evaluation will occur periodically during the sampling schedule outlined in this SAP. Necessary revisions may include but are not limited to site locations, field forms, sample methods and logistics. Any revisions will be included as amendments to this SAP. In collaboration with Aethon, the WDEQ project manager will notify all associated field personnel, landowners and partners of amendments to this SAP along with implementation of any corrective actions.

Sampling

Description of Study Area

Badwater Creek drains an 856 square mile watershed and is primarily situated within the Bighorn Salt Desert Shrub Basins, Foothill Shrublands and Low Mountains, Bighorn Basin, and Rolling Sagebrush Steppe level IV ecoregion within the greater Wyoming Basin level III ecoregion (Chapman et al. 2003). Badwater Creek flows west to its confluence with Alkali Creek and then to Boysen Reservoir. Bridger, Dry, Hoodoo and Alkali Creeks upstream of Moneta Divide effluent discharge are intermittent and ephemeral prior to their confluences with Badwater Creek. Because of permitted produced water effluent discharge, Alkali Creek downstream of Moneta Divide is a perennial stream. Between Boysen Reservoir and the Badwater-Alkali Creek confluence, Badwater Creek is intermittent.

Land ownership along Badwater Creek is mostly private interspersed with Boysen State Park (BSP), Bureau of Land Management (BLM) and State of Wyoming parcels (Figure 2). Primary land uses in the Badwater Creek watershed include livestock grazing, wildlife habitat and recreation, irrigated agriculture, and oil and gas production. Permitted point source discharges in the watershed include the aforementioned outfalls from the Moneta Divide oil and gas field and the Burlington Resources Oil and Gas Company, Inc., associated with the Lost Cabin gas plant.

Figure 1. Badwater Creek watershed with Wyoming Basin Level IV ecoregions and approximate site locations.

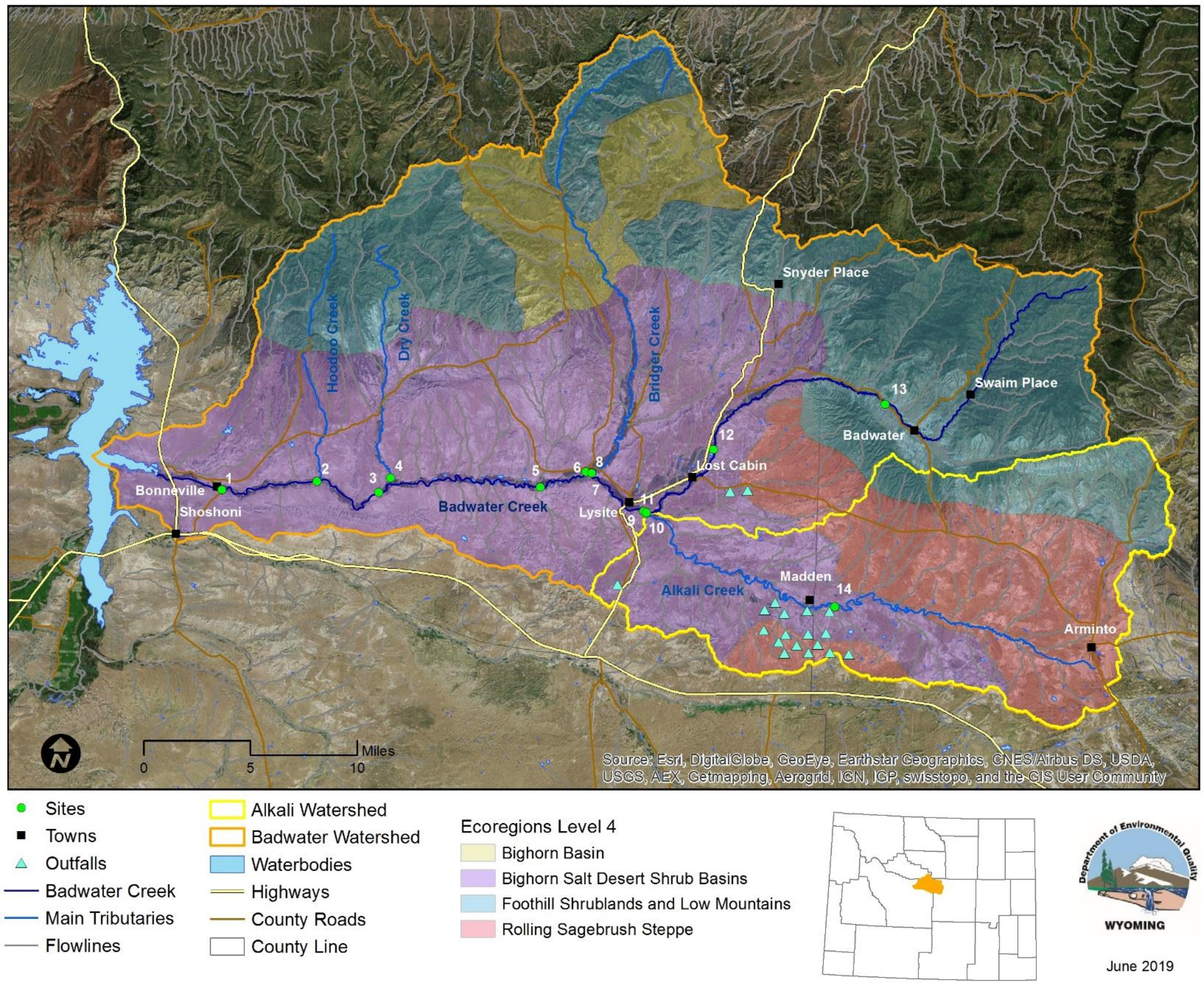
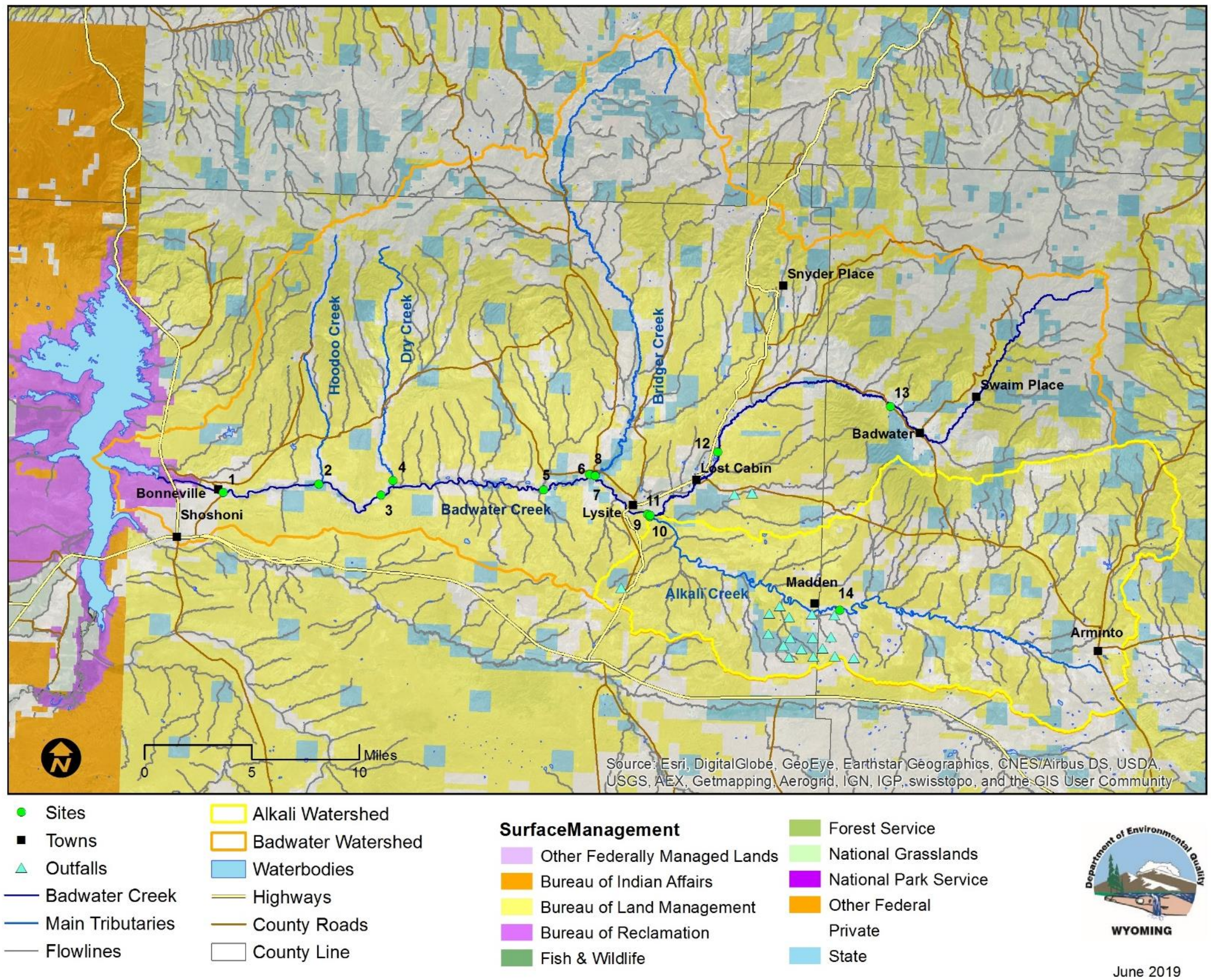


Figure 2. Badwater Creek watershed with land ownership and approximate site locations.



Study Design
Sampling will be a combined gradient, above/below, and local reference study design:

a) Gradient: Used to evaluate spatial and temporal trends in chemical, physical, and biological condition along Badwater Creek.
b) Above/Below: Used to evaluate spatial and temporal trends in chemical, physical, and biological condition upstream and downstream of known anthropogenic influences.
c) Local reference: Used to help establish chemical, physical, and biological conditions with minimal anthropogenic influence.

Site Selection
Thirteen sites will be selected for this study to represent the chemical, physical, and biological conditions within Badwater Creek and its tributaries, Alkali, Bridger and Dry Creeks (Table 1). An additional site on Alkali Creek above Aethon outfalls (site 14) may be included if flowing water is present. Final study sites may vary slightly following site reconnaissance and depending on WDEQ's ability to obtain permission and to access the sites, as well as whether the proposed site sufficiently achieves the intended objective.

Table 1. Proposed sampling sites in Badwater Creek watershed

Site ID	Waterbody	Description	Sample	Latitude	Longitude	Ownership
1	Badwater Creek	Near Bonneville Road	C,P,D	43.26674	-108.06895	Two-B Land & Livestock Co, Inc.
2	Badwater Creek	Below Hoodoo Creek	C,B	43.27460	-107.98106	State of Wyoming
3	Badwater Creek	Below Dry Creek	C,P,D	43.26871	-107.92332	Picard Livestock Co
4	Dry Creek	Dry Creek terminus	C,B,P	43.27873	-107.91266	Picard Livestock Co
5	Badwater Creek	Below Schoening Creek	C,B,P,D	43.27594	-107.77348	Gardner Livestock LLC
6	Badwater Creek	Below Bridger Creek	C,B,P	43.28736	-107.73149	State of Wyoming
7	Bridger Creek	Bridger Creek terminus	C,B,P	43.28708	-107.72602	State of Wyoming
8	Badwater Creek	Above Bridger Creek	C,P	43.28678	-107.72628	Montex Drilling Co
9	Badwater Creek	Below Alkali Creek	C,B,P,D	43.26195	-107.67654	Louisiana Land & Exploration Co
10	Alkali Creek	Alkali Creek terminus	C,P	43.26012	-107.67472	BLM
11	Badwater Creek	Above Sand Draw	C,B,P,D	43.26119	-107.67404	BLM
12	Badwater Creek	Above Lost Cabin	C,B,P,D	43.30530	-107.61383	Louisiana Land & Exploration Co
13	Badwater Creek	Upper Watershed	C,B,P,D	43.33956	-107.45530	BLM
14	Alkali Creek	Above Outfalls	C, B, P	43.201331	-107.496825	BLM

Sample abbreviations: C, chemical; B, biological; D, pressure transducer and temperature logger; P, physical.

Monitoring and Access Permissions
Landowner permission is obtained before accessing and monitoring on private property. Landowner permission is obtained for access and monitoring at the sampling site(s) prior to any field reconnaissance and the first round of data collection as described in this SAP. Documentation of securing permissions to access and monitor are on file at the WDEQ Cheyenne office. Routes used to access monitoring sites are approximated in Appendix A. For the collection of fish, a Chapter 33 Permit for Scientific Research, Education/Display, or Special Purposes was obtained from the Wyoming Game and Fish Department.

Primary Field Personnel

Sampler	Organization	Office	Title	Training / Education
Michael Thomas	WDEQ	Cheyenne WY	Surface Water Quality Standards, Natural Resource Analyst	NA
Tavis Eddy	WDEQ	Lander, WY	Monitoring Program, Natural Resource Analyst	NA
Michael Wachtendonk	WDEQ	Lander, WY	Monitoring Program, Natural Resource Analyst	NA
Eric Hargett	WDEQ	Cheyenne, WY	Monitoring Program, Assistant Supervisor	NA
Jamie Kuklok	Inberg-Miller Engineers	Casper, WY	Environmental Scientist	Bachelor of Science in Biology; 13 years environmental monitoring experience and strong background in water sampling
Mike Cox	ERM	Livingston, MT	Water Resources Engineer	Over 20 years' experience in surface water hydrology, i.e., modeling, floodplain studies, fisheries, stream gauge network; provided support for Moneta Divide since 2009
Joe Kmetz	ERM	Livingston, MT	Water Resources Engineer	Over 20 years' experience in surface water hydrology, i.e., modeling, floodplain studies, fish passage, stream gauge; worked on Alkali Creek channel stability project
Andy Olson	ERM	Livingston, MT	Water Resources Engineer	Four years' experience in stream monitoring; worked on Alkali Creek channel stability project

Primary Data Interpreters

Personnel	Organization	Office	Title	Training / Education
Lindsay Patterson	WDEQ	Cheyenne WY	Surface Water Quality Standards Supervisor	NA
Michael Thomas	WDEQ	Cheyenne, WY	Surface Water Quality Standards Natural Resource Analyst	NA
Jamie Kuklok	Inberg-Miller Engineers	Casper, WY	Environmental Scientist	see above
Mike Cox	ERM	Livingston, MT	Water Resources Engineer	see above
Joe Kmetz	ERM	Livingston, MT	Water Resources Engineer	see above
Andy Olson	ERM	Livingston, MT	Water Resources Engineer	see above

Personnel	Organization	Office	Title	Training / Education
Shwet Prkash	ERM	Livingston, MT	Water Resources, Climate Change and Modeling Group, Manager	Over 15 years' experience directing projects that include hydrodynamic studies, groundwater contamination, fate and transport, sediment studies, and TMDL development; worked on Moneta Divide Boysen Reservoir modeling and Badwater UAA since early 2017
William Schew	ERM	Livingston, MT	Principal Consultant	PhD from University of Pennsylvania; over 30 years' experience in water resource and permitting projects, including stream reclassification, establishing thermal/chemical limits; water conservation and groundwater mitigation; worked on Moneta Divide Boysen Reservoir modeling and Badwater UAA since May 2017
Kelli Kearns	ERM	Livingston, MT	Environmental Engineer	Over two years' experience in water resources and water quality modeling, including risk assessment and compliance, and modeling for natural/engineered systems; worked on the Moneta Divide Reservoir modeling study since June 2017
Michael Fichera	ERM	Livingston, MT	Environmental Engineer	Over 25 years' experience in water quality modeling, oil/chemical spills, oil toxicity assessments, deposition modeling, damage assessments, TMDL development and project management; worked on Moneta Divide Boysen Reservoir modeling study and Badwater UAA in early 2017

Sample Parameters and Methods

Parameter	Sample Method / SOP *	Reporting Units	Analytical Method	Preservative**	Holding Time	Reporting Limit
Chemical (Laboratory)						
Alkalinity (as $CaCO_3$), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	mg/L	SM2320-B-2011	Iced to $\leq$ 6ºC	14 days	10.0
Aluminum (Al), dissolved	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	Filter (0.45 micron), 1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	50.0
Ammonia-Nitrogen, Total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	SM4500-NH_3D	1:1 H_2SO_4 to pH $\leq$ 2, Iced to $\leq$ 6ºC	28 days	50.0
Antimony (Sb), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	10.0
Arsenic (As), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	1.0
Arsenic (As), dissolved	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	Filter (0.45 micron), 1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	1.0
Barium (Ba), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	10.0
Beryllium (Be), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	1.0
Ca, Mg, K, Na (dissolved)	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	mg/L	E200.7	Filter (0.45 micron), 1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	1.0
Cadmium (Cd), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	0.1
Cadmium (Cd), dissolved	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	Filter (0.45 micron), 1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	0.1
Chloride (Cl)	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	mg/L	E300.0-R2.1	Iced to $\leq$ 6ºC	28 days	1.0
Chromium (Cr), total	Grab / See SOP for *Chemical Grab*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	5.0

Parameter	Sample Method / SOP *	Reporting Units	Analytical Method	Preservative**	Holding Time	Reporting Limit
	Sampling Procedure - Lotic					
Copper (Cu), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	5.0
Copper (Cu), dissolved	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	Filter (0.45 micron), 1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	5.0
Dissolved Organic Carbon	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	mg/L	SM5310-B	Filter (0.45 micron), 1:1 HCl to pH $\leq$ 2, Iced to $\leq$ 6ºC	28 days	1.0
Fluoride	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	mg/L	SM4500-F-C	Iced to $\leq$ 6ºC	28 days	0.1
Hardness, Total (as $CaCO_3$)	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	mg/L	SM2340-B-2011	NA (calculated)	NA	10.0
Iron (Fe), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	50.0
Iron (Fe), dissolved	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	Filter (0.45 micron), 1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	50.0
Lead (Pb), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	1.0
Lead (Pb), dissolved	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	Filter (0.45 micron), 1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	1.0
Mn (dissolved)	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	Filter (0.45 micron), 1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	1.0
Nickel (Ni), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	10.0
Nickel (Ni), dissolved	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	Filter (0.45 micron), 1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	10.0
Nitrogen, Total (TN)	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	SM4500-N-B-2011	1:1 H_2SO_4 to pH $\leq$ 2, Iced to $\leq$ 6ºC	28 days	100.0

Parameter	Sample Method / SOP *	Reporting Units	Analytical Method	Preservative**	Holding Time	Reporting Limit
Nitrogen, Nitrate-Nitrite (as N)	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	SM4500-NO3-F-2011	1:1 H_2SO_4 to pH $\leq$ 2, Iced to $\leq$ 6ºC	28 days	50.0
Phosphorus, Total (TP)	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	SM4500-P-E-2011 or SM 4500-P-I-2011	1:1 H_2SO_4 to pH $\leq$ 2, Iced to $\leq$ 6ºC	28 days	10.0
Selenium (Se), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	1.0
Selenium (Se), dissolved	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	Filter (0.45 micron), 1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	1.0
Silver (Ag), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	0.5
Silver (Ag), dissolved	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	Filter (0.45 micron), 1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	0.5
Sulfates (SO_4)	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	mg/L	E300.0-R2.1	Iced to $\leq$ 6ºC	28 days	2.0
Sulfide, Hydrogen Sulfide, Total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	mg/L	SM4500-S_2-D	4 mL ZnAc, zero headspace, NaOH to pH >9, Iced to $\leq$ 6ºC	7 days	0.05
Thallium (Tl), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	1.0
Total Dissolved Solids (TDS)	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	mg/L	SM2540-C	Iced to $\leq$ 6ºC	7 days	10.0
Uranium (U), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	0.5
Zinc (Zn), total	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	10.0
Zinc (Zn), dissolved	Grab / See SOP for *Chemical Grab Sampling Procedure - Lotic*	µg/L	E200.8	Filter (0.45 micron), 1:1 HNO_3 to pH $\leq$ 2, Iced to $\leq$ 6ºC	6 months	10.0
Chemical (Field)						
Conductivity	See SOP for *Conductance,*	µS/cm	SM2510-B	None, FM	NA	0.10

Parameter	Sample Method / SOP *	Reporting Units	Analytical Method	Preservative**	Holding Time	Reporting Limit
	Specific (Conductivity)					
Dissolved Oxygen	See SOP for *Dissolved Oxygen (DO)*	mg/L; % saturation	ASTM D 885-05 / SM4500-O-G / E360.1	None, FM	NA	0.10
pH	See SOP for *pH*	SU	SM4500-H^+B	None, FM	NA	0.0-14.0 ± 0.2
Turbidity	See SOP for *Turbidity*	NTU	SM2130-B	None, FM	NA	0.02
Temperature, Water	See SOP for *Temperature, Water* and *Temperature Logger Calibration and Placement - Wadeable Streams and Rivers*	ºC	SM2550-B / See SOP for *Temperature Logger Calibration and Placement - Wadeable Stream and Rivers*	None, FM	NA	± 0.10
Biological						
Macroinvertebrates	See SOP for *Macroinvertebrate Sampling – Multi-habitat Method. For using Hester-Dendy artificial substrates, see Wisconsin DNR Water Quality Monitoring Program SOP (Jan 2015) Large River Macroinvertebrate Sampling V2.0 (Appendix B).*	Presence / Absence	SOP for *Macro-invertebrate Sample Identification. Sampling will be used for presence/absence determination*	99% Ethyl Alcohol; see SOP for *Macro-invertebrate Sample Preservation*	Indefinite	NA
Fish	See South Dakota DENR Watershed Protection Program SOP (Jan 2017) *Fish Collection Methods for Wadeable Streams in South Dakota* (Appendix C). Voucher specimens will be collected and preserved for each species, including photo ID for large individuals; 3rd party will confirm fish identification. Samplers must	Presence / Absence	See South Dakota DENR Watershed Protection Program SOP (Jan 2017) *Fish Collection Methods for Wadeable Streams in South Dakota* (Appendix C).	10% formalin; See South Dakota DENR Watershed Protection Program SOP (Jan 2017) *Fish Collection Methods for Wadeable Streams in South Dakota* (Appendix C).	Indefinite	NA

Parameter	Sample Method / SOP *	Reporting Units	Analytical Method	Preservative**	Holding Time	Reporting Limit
	obtain and carry sampling permits.					
Physical						
Aquatic Habitat	Site observations	NA	NA	NA	NA	NA
Discharge	See SOP for *Stream Discharge - Wadeable Streams and Rivers*	cfs	See SOP for *Discharge - Wadeable Streams and Rivers*	None, FM	NA	0.01
Stage (pressure transducer)	See Aethon SOP: *Standard Operating Procedures for Establishing and Monitoring Gauge Stations* (Appendix D).	feet	See Aethon SOP: *Standard Operating Procedures for Establishing and Monitoring Gauge Stations* (Appendix D).	NA	NA	0.1

Abbreviations: SOP, Standard Operating Procedure (unless otherwise stated all SOPs can be found in WDEQ 2018b); FM, Field Measurement.
* Data collection methods typically follow referenced standard operating procedures, however, modifications may be made on a case by case basis. Modifications to the method will be documented either in the SAP or within the Methods section of publications presenting the data.
** Samples for Ammonia-Nitrogen, Total, Nitrogen, Total (TN), Nitrogen, Nitrate-Nitrite (as N) and Phosphorus, Total (TP) should be preserved to a pH $\leq$ 2 but not less than a pH of 1.0.

Study Duration

The study is anticipated to begin in April 2019 and conclude January 2020, with the potential to extend further into 2020 if additional data are deemed necessary.

Monitoring Schedule

Parameters	Sample Event	Sample Period	Sample Frequency
Chemical and Physical	All conditions	Biweekly/Monthly	Minimum 12x per year (potentially more during spring runoff or variable oil & gas operations)
Chemical and Physical (pressure transducer and temperature data loggers)	Ice Free Period of Approximately March through November	Continuous	Hourly
Biological (multi-habitat macroinvertebrate sampling and fish collections)	End of spring runoff	Approximately 2-3 days in in early July	1x per site per year
Biological (artificial substrates)	End of spring runoff	Spring / summer 2019	Minimum 1x per site for a 4-5 week deployment

Quality Assurance/Quality Control (QA/QC)

Data Recording

All chemical, biological (i.e., multi-habitat and artificial substrate macroinvertebrate sampling) and physical data and observational information collected in the field will be recorded on appropriate sections of WDEQ Field Data Sheets (see SOP for *Monitoring Procedure Sequence (standard)*). Fish collection data will be recorded using Wyoming Game and Fish Department Field Data Sheets similar to those presented

in Appendix C. Samples for laboratory analysis will be recorded on official chain of custody forms (see SOP for *Chain of Custody*).

Sample Labeling
See SOPs for *Sample Labeling* and *Macroinvertebrate Sampling – Multi-habitat Method*.

Data Verification and Validation
See SOPs for *Data Validation* and *Data Verification*.

Field Quality Control (QC)

Field QC Samples	Collection Frequency	Parameters
Field Blank	At least 10% of all collected samples	Chemical (grab samples)
Duplicate	At least 10% of all collected samples	Chemical (grab samples), Biological

See SOP for *Blanks, Duplicates, Precision* and *Quality Control Measures, Summary of*

Data Objectives and Reconciliation
WDEQ water quality projects will follow the SOPs for each particular project needed. Data quality objectives in terms of accuracy, precision and completeness for water quality parameters are listed in the table below.

Parameter	Precision *	Accuracy	Completeness	Method
Temperature	±10%	**	95%	See SOP for *Temperature, Water*
pH	±0.3 S.U.	**	95%	See SOP for *pH*
Conductivity	±10%	**	95%	See SOP for *Conductance, Specific (Conductivity)*
Dissolved oxygen	±10%	**	95%	See SOP for *Dissolved Oxygen*
Turbidity	±20%	**	95%	See SOP for *Turbidity*
Alkalinity, Total (as $CaCO_3$)	±10%	90 – 110%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Aluminum, dissolved (Al)	±20%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Ammonia-Nitrogen, Total	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Antimony, Total (Sb)	±20%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Arsenic, Total (As)	±20%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Arsenic, Dissolved (As)	±20%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Barium, Total (Ba)	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Beryllium, Total (Be)	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*

Parameter	Precision *	Accuracy	Completeness	Method
Ca, Mg, K, Na (dissolved)	±20%	85 – 115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Cadmium, Total (Cd)	±15%	90-110%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Cadmium, Dissolved (Cd)	±15%	90-110%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Chloride (Cl)	±10%	90 – 110%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Chromium, Total (Cr)	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Copper, Total (Cu)	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Copper, Dissolved (Cu)	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Dissolved Organic Carbon	±15%	80-120%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Fluoride	±20%	80-120%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Hardness, Total (as $CaCO_3$)	NA	NA	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Iron, Total (Fe)	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Iron, Dissolved (Fe)	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Lead, Total (Pb)	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Lead, Dissolved (Pb)	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Manganese, Dissolved (Mn)	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Nickel, Total (Ni)	±20%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Nickel, Dissolved (Ni)	±20%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Nitrogen, Nitrate-Nitrite (as N)	±15%	85 – 115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Nitrogen, Total (TN)	±15%	85 – 115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Phosphorus, Total (TP)	±15%	85 – 115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Selenium, Total (Se)	±20%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Selenium, Dissolved (Se)	±20%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Silver, Total (Ag)	±20%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Silver, Dissolved (Ag)	±20%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Sulfates (SO_4)	±15%	85 – 115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*

Parameter	Precision *	Accuracy	Completeness	Method
Sulfide, Hydrogen Sulfide, Total	±30%	70-130%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Thallium, Total (Tl)	±20%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Total Dissolved Solids (TDS)	±15%	69 – 131%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Uranium, Total (U)	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Zinc, Total (Zn)	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Zinc, Dissolved (Zn)	±15%	85-115%	95%	Grab / See SOP for *Chemical Grab Sampling Procedure – Lotic*
Macroinvertebrates	NA (presence / absence only)	NA	95%	See SOP for *Macroinvertebrate Sampling – Multi-habitat Method*
Fish	total taxa ±15%	NA	95%	See South Dakota DENR Watershed Protection Program SOP (Jan 2017) *Fish Collection Methods for Wadeable Streams in South Dakota* (Appendix B). Voucher specimens will be collected and preserved for each species, including photo ID for large individuals; 3rd party will confirm fish identification. Samplers must obtain and carry sampling permits.
Discharge	NA	NA	95%	See SOP for *Stream Discharge - Wadeable Streams and Rivers*

***** *Reporting Limit (RL) Range can impact precision criteria; see SOP Precision (Field Duplicates).*

****** *Accuracy for parameters calibrated to a known standard is assumed.*

Data collected under this SAP will be evaluated by the QA/QC Officer with respect to the aforementioned data objectives. If it is determined that one or more data objectives/components were not met, the Project Manager and Surface Water Quality Standards Program Supervisor will be informed and given an opportunity to provide justification to the QA/QC Officer as to whether the particular data objective/component should be qualified or rejected and if future data components/objectives should be altered.

Equipment (Electronic) Calibration, Maintenance and Calibration Logs

Item	Calibration	Calibration Check	Maintenance	Calibration Log
pH probe (Hydrolab MS5*)	At least once daily with pH 7 & 10 standards	At least once weekly with pH 7 standard	Re-condition according to owner's manual. Remove precipitate/debris and keep probe bulb moist	See SOP for *Instrument Calibration and Calibration Logs*
Conductivity probe (Hydrolab MS5*)	At least once daily with either 100 or 1000 µS/cm standard or 12.89 and 50.00 mS/cm when applicable	At least once weekly with 100 or 1000 µS/cm standard	Re-condition according to owner's manual. Remove precipitate/debris	See SOP for *Instrument Calibration and Calibration Logs*

Item	Calibration	Calibration Check	Maintenance	Calibration Log
Flow meter (Marsh McBirney Flow-mate 2000 #2005697 and #2005722**)	After each battery charge	None	Remove precipitate/debris	See SOP for *Instrument Calibration and Calibration Logs*
LDO probe (Hydrolab MS5*)	At least once daily or with each 500 ft change in elevation	At least once weekly with air saturated water at a known barometric pressure	Re-condition according to owner's manual. Remove precipitate/debris and keep probe bulb moist	See SOP for *Instrument Calibration and Calibration Logs*
Turbidimeter (HACH 2100 #000400024844***)	At least once monthly with Formazin or GelEx Standards	At least once monthly with Formaxin or GelEx Standards	See owner's manual	See SOP for *Instrument Calibration and Calibration Logs*
Levelogger (Solonist 3001 LT Levelogger Edge, #0022101650, #0022101691, #0022101659, #0022101669, #0022101680, #0022101668) Barologger (Solinst 3001 LT Barologger Edge, #0012101619, #0012101608)	Temperature: before and after deployment with ice water bath and NIST certified thermometer. Pressure: before and after deployment by comparing transducer data to staff gage or by measuring the depth of water over the transducer with a stadia rod or other measuring device.	Temperature: at deployment and retrieval using certified NIST thermometer in stream at location of logger set-up. Pressure: make periodic staff gage readings to detect any shift or drift in the transducer data.	Re-condition according to owner's manual. Remove debris and ensure positioning in stream/on rebar	See SOP for *Instrument Calibration and Calibration Logs* See Aethon SOP: *Standard Operating Procedures for Establishing and Monitoring Gauge Stations* (Appendix C).
Time-lapse camera (Brinno TLC 200 Pro, #TEI3000291. #TEI3000920, #TEI3000908, #TEI3000930, #TEJ2300256, #TEJ2300073, #TEJ2300249, #TEJ2300256, #TEJ2300128)	None	None	Check battery level and replace batteries	None
Backpack Electroshocker (Smith-Root LR-24, #D00915)	None	None	Check battery level and replace batteries	None

*Hydrolab MS5 SN: 07500045312; if equipment are unavailable, other Hydrolab equipment may be used, e.g., Hydrolab MS5 SN: 140600065731
** If equipment are unavailable, other flow meters may be used, e.g., HACH FH 950 SN: 132041001614
*** If equipment are unavailable, other turbidimeters may be used, e.g., HF Scientific MicroTPI #20008 SN: 510082
Unless otherwise noted all SOPs can be found in WDEQ 2018b.

Field Audits

A field audit by WDEQ QA/QC Officer will be accommodated if requested.

Laboratories

The following laboratories will provide analytical services for samples collected as part of the project described in this SAP:

1. WDEQ, Water Quality Division Laboratory (WQD Lab)
   The WQD lab will be the provider of analytical services for water chemistry samples collected as part of this project by WQD staff. The WQD Lab will provide customized packages of bottles, labels, preservatives and chain of custody forms prior to samples being collected and as requested by samplers. Samplers will send samples to WQD Lab within one week of collection using United Parcel Service, Federal Express or hand delivery. The WQD Lab will analyze samples in accordance with established standards for holding time, analytical method and data QA/QC. The WQD Lab will follow Watershed Protection Program SOPs (WDEQ 2018b) and QAPP (WDEQ 2018a).

2. Wyoming Game and Fish Department Laboratory (Game and Fish Lab)
   The Wyoming Game and Fish Laboratory in Laramie, WY will provide third party confirmation of voucher fish specimens and fish identification. The Game and Fish Laboratory will inform primary field personnel of the appropriate sampling containers, labels, preservatives and chain of custody forms prior to fish collection. The Game and Fish Laboratory will sort and identify specimens according to relevant SOPs and standards for taxonomic identification.

3. Contract Laboratory (Rhithron Associates)
   Rhithron Associates out of Missoula, MT (or another suitable laboratory) will provide taxonomic identification services for macroinvertebrate samples collected as part of this project. Preserved macroinvertebrates samples will be sent to the contract laboratory after each sample period. The contract laboratory will subsample, sort and identify specimens according to contract terms and relevant SOPs. Established standards for taxonomic identification will be followed as identified in the contract for services.

Data

Data Management

Data Type	Storage	Location
Chemical	SWM 2.0 database, spreadsheet, .pdf	WDEQ Cheyenne
Biological	SWM 2.0 database, spreadsheet, .pdf	WDEQ Cheyenne
Physical	SWM 2.0 database, spreadsheet, .pdf	WDEQ Cheyenne

Data Archiving

Data Item	Format	Backup Copy & Format	Location	Retention
Field Data Sheets	Paper	Electronic (.pdf)	WDEQ Cheyenne	Permanent
Photographs	Electronic (.jpg and .wpd) & paper	Electronic (.jpg and .wpd)	WDEQ Cheyenne	Permanent
Field Log Books	Paper	Electronic (.pdf)	WDEQ Cheyenne	Permanent
Laboratory Results / QA	Electronic (.csv, .pdf) & paper	Electronic (.csv, .pdf) & paper	WDEQ Cheyenne	Permanent
Calibration Logs	Paper	Electronic (.pdf)	WDEQ Cheyenne	Permanent
Chain of Custody	Electronic (.xlsx, .pdf) & paper	Electronic (.xlsx) & paper	WDEQ Cheyenne	Permanent
Spreadsheets, other electronic files	Electronic (.xlsx, .txt, .dbf, other) & paper	Electronic (.xlsx, .txt, .dbf, other) & paper	WDEQ Cheyenne	Permanent

Data Item	Format	Backup Copy & Format	Location	Retention
Databases	Electronic (.mdb, other)	Electronic (.mdb, other)	WDEQ Cheyenne	Permanent
Fish voucher specimens	Preserved in containers with formalin	Photo ID of large individuals	Game and Fish Laboratory	Indeterminate

- All records are the property of the State of Wyoming and therefore subject to the Wyoming Public Records Act.
- Records may be transferred to the Wyoming State Archives according to procedures in the Wyoming Records Management Manual.

Data Analysis

Analytical methods used for this study include but are not limited to the following:

Data Type	Analytical Methods
Chemical (all)	Chemical data will be evaluated to: 1) determine whether current water quality criteria are appropriate; 2) if appropriate, establish site-specific water quality criteria protective of designated uses.
Biological (macroinvertebrate and fish)	Biological data will be evaluated to determine: 1) whether the biological communities in Badwater Creek are similar upstream and downstream of Alkali Creek and therefore whether ambient water quality downstream of Alkali Creek is protective of current designated uses; 2) the composition of the aquatic community expected to occur in Badwater Creek to evaluate whether nationally recommended water quality criteria are appropriate or should be modified; 3) the composition of the aquatic community expected to occur in Badwater Creek to help determine whether alternative water quality criteria can be derived; 4) whether the current designated uses are appropriate for Badwater Creek and, if not appropriate, what designated uses should be applied.
Physical (discharge)	Physical data (i.e., discharge) will be used to characterize the hydrologic regime of the Badwater Creek watershed and the impacts of the oil field on the chemical, physical, and biological conditions within the Badwater Creek watershed.
Chemical, biological and/or physical	Other methods as appropriate may be used to evaluate chemical, biological and/or physical data and potentially establish appropriate water quality criteria and designated uses for Badwater Creek.

Reports

If appropriate, data, analyses, results and conclusions from this study will be used to develop: 1) a proposal for site-specific chloride criteria; 2) a proposal for other site-specific water quality criteria; and 3) use attainability analyses if changes to designated uses are warranted. Options for developing site-specific criteria include: deriving a criteria to protect the current designated uses (cold water game fish, nongame fish, aquatic life other than fish); deriving criteria to protect current and expected uses if it can be shown that the current water quality criteria are not attainable due to one of the six factors described in Chapter 1, Section 33 (WDEQ/WQD 2018); or establishing narrative criteria and methods to interpret the narrative for assessment and permitting purposes.

References

Chapman, S.S., S.A. Bryce, J.M. Omernik, D.G. Despain, J. ZumBerge and M. Conrad. 2003. Ecoregions of Wyoming (color poster with map, descriptive text, summary tables and photographs). Reston, Virginia. United States Geological Survey (map scale 1:1,400,000).

State of South Dakota, Department of Environment and Natural Resources, Watershed Protection Program. 2017. Standard Operating Procedures for Field Parameters: Volume II Revision 3.1: Biological and Habitat Related Techniques. SD DENR/WPP, Pierre, South Dakota.

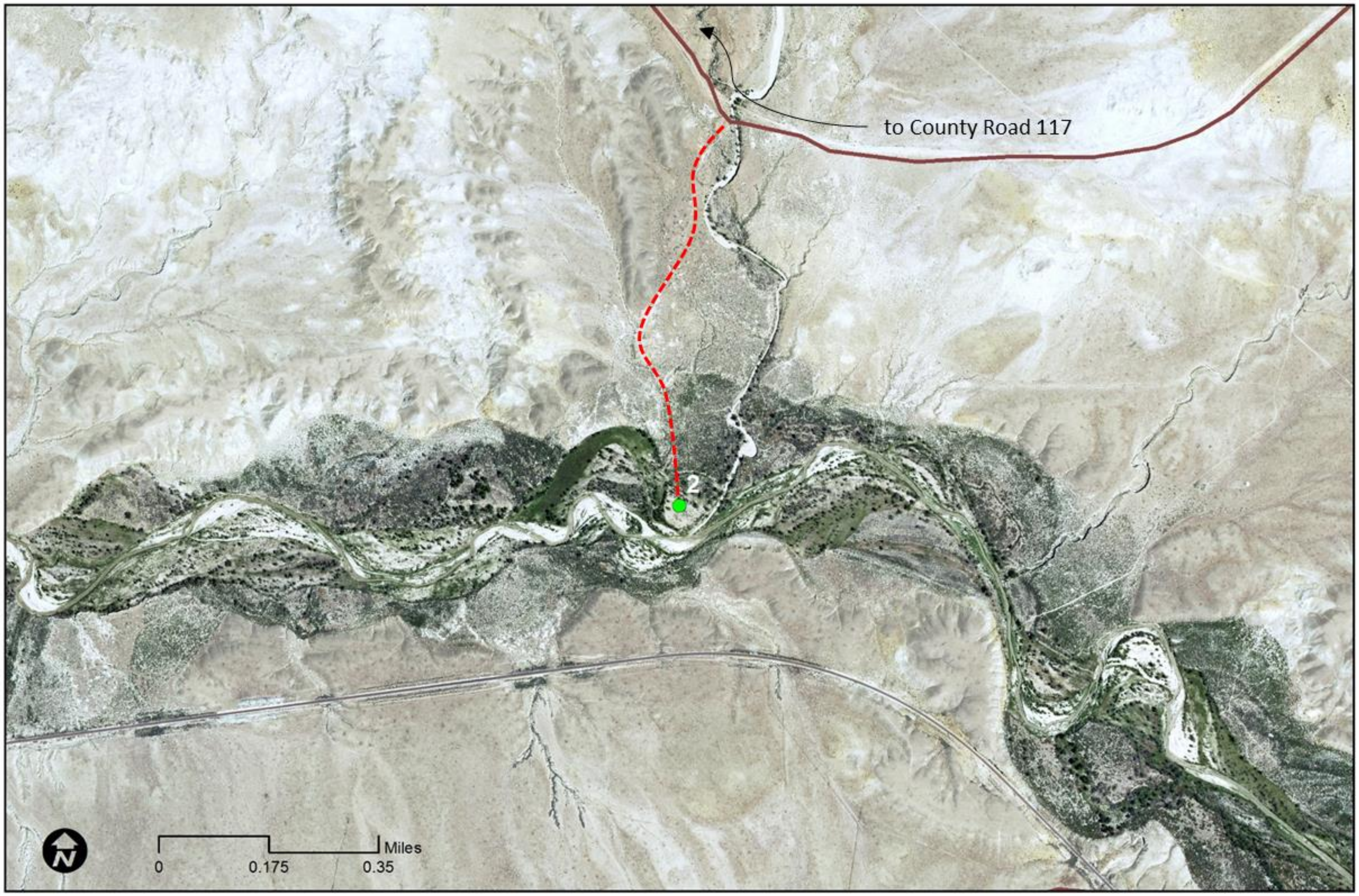
WDEQ/WQD. 2018a. Quality Assurance Project Plan (QAPP) for Watershed Protection Program Water Quality Monitoring. Wyoming Department of Environmental Quality, Water Quality Division, Cheyenne, Wyoming.

WDEQ/WQD. 2018b. Manual of Standard Operating Procedures for Sample Collection and Analysis. Wyoming Department of Environmental Quality, Water Quality Division, Cheyenne, Wyoming.

WDEQ/WQD. 2018. Wyoming Water Quality Rules and Regulations – Chapter 1. Wyoming Department of Environmental Quality, Water Quality Division, Cheyenne, Wyoming.

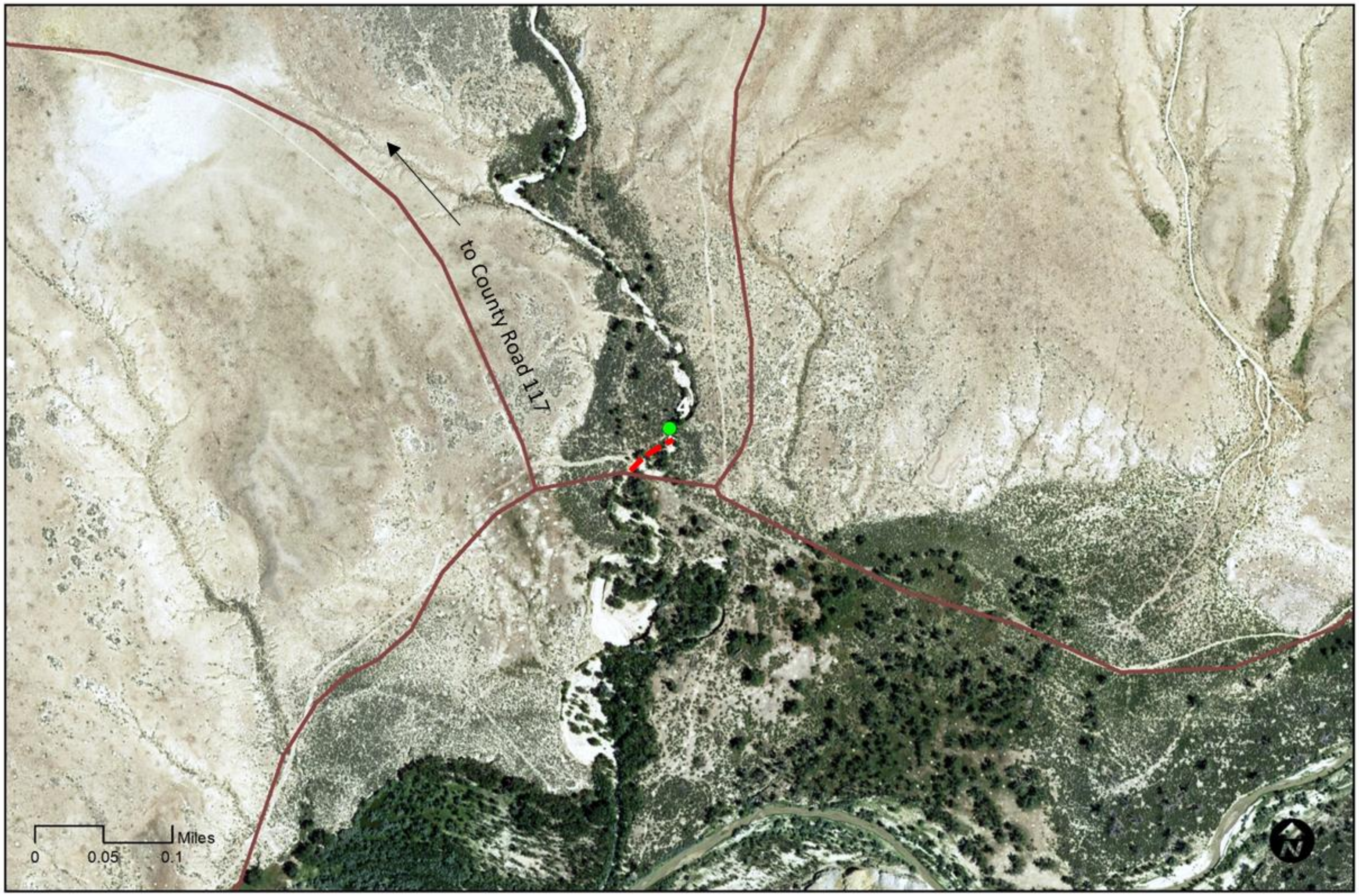
Appendix A. Maps illustrating the approximate location of Badwater Creek monitoring sites (green circle) and access routes (red dashed lines).

Sampling Site 1 - Badwater Creek near Bonneville Road

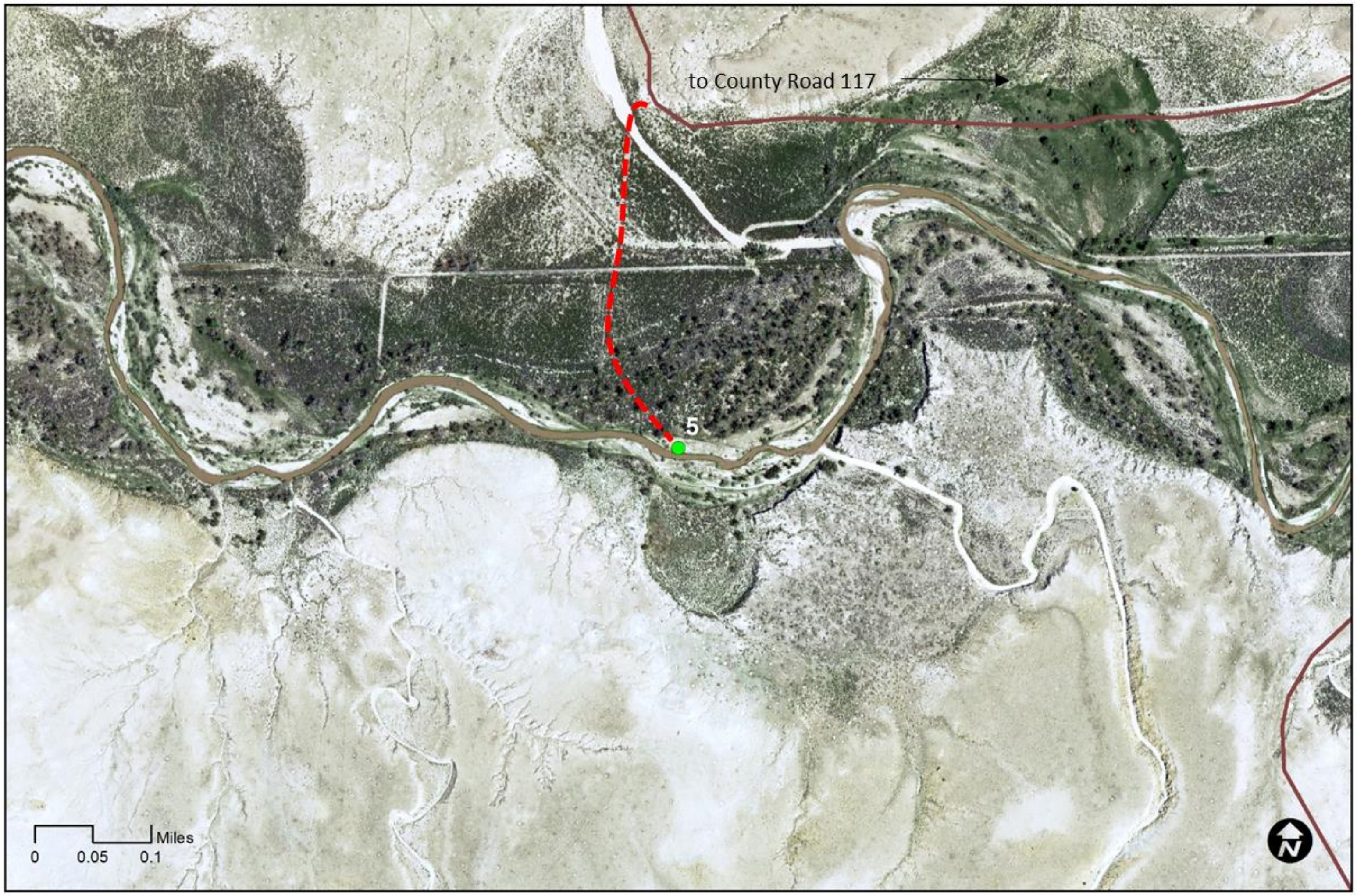


Sampling Site 2 - Badwater Creek below Hoodoo Creek

Sampling Site 3 - Badwater Creek below Dry Creek



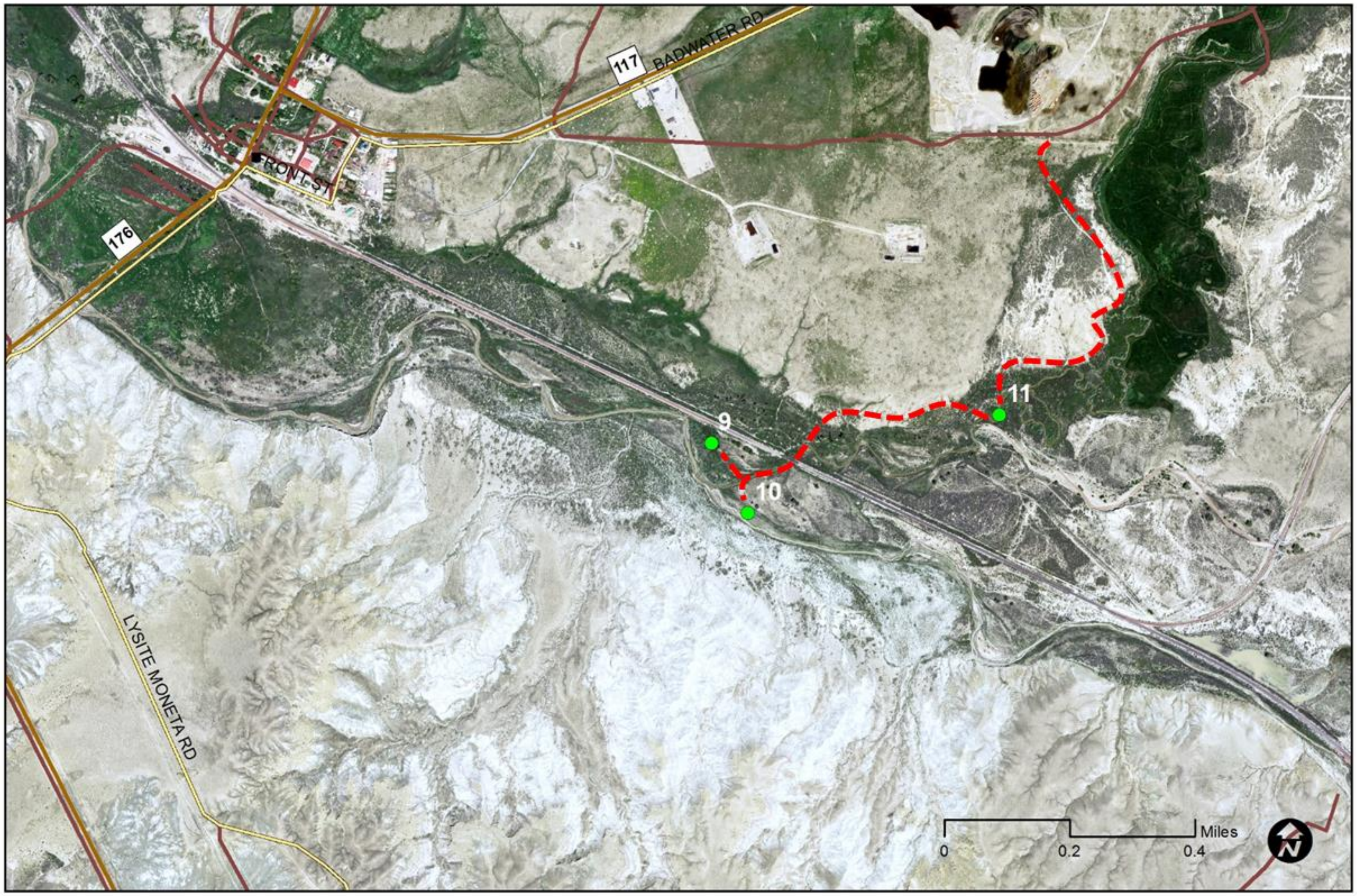
Sampling Site 4 - Dry Creek near Badwater Creek confluence



Sampling Site 5 - Badwater Creek below Schoening Creek

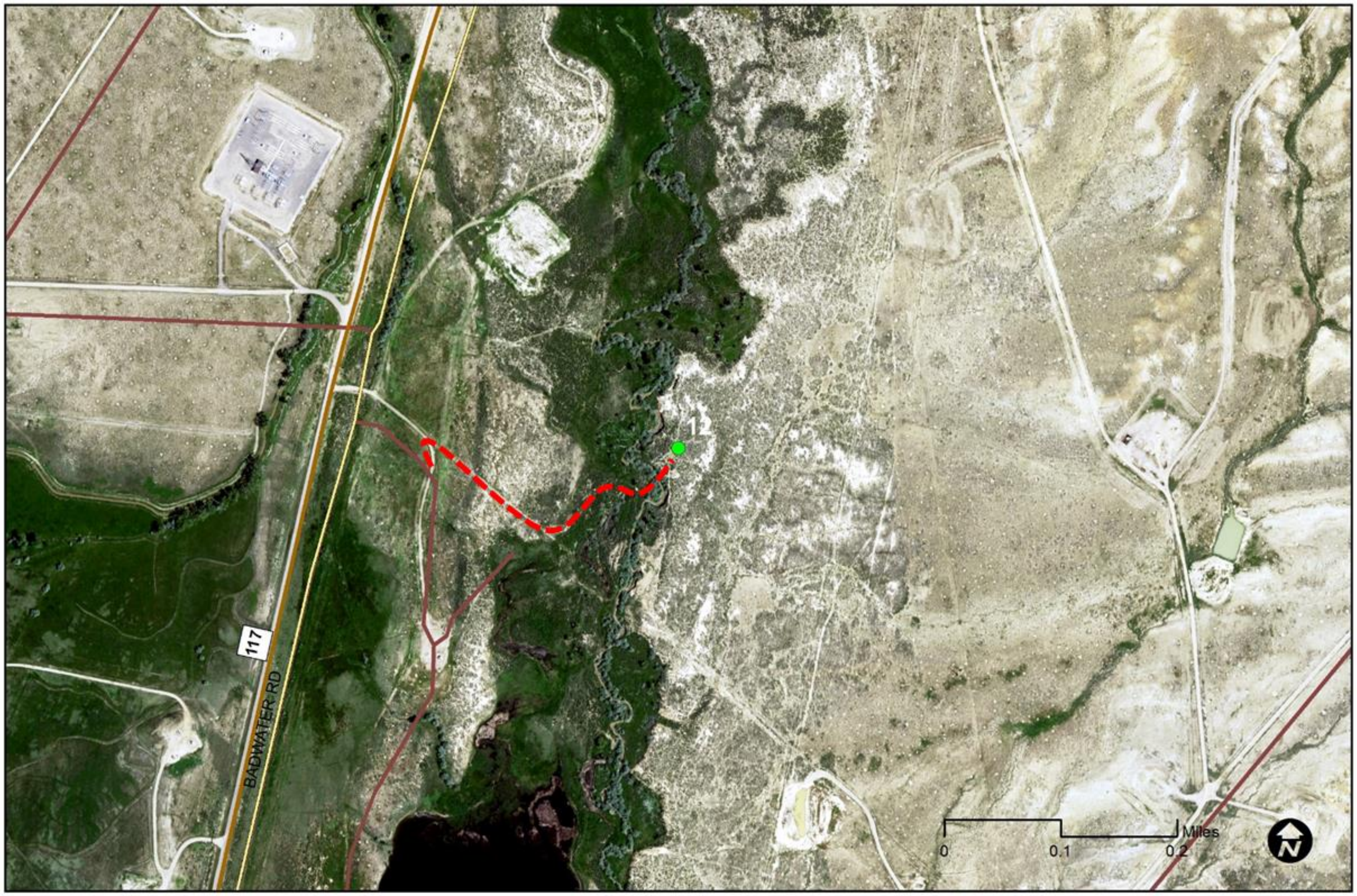
Sampling Sites 6 (Badwater Creek below Bridger Creek), 7 (Bridger Creek near Badwater Creek confluence)

and 8 (Badwater Creek above Bridger Creek)

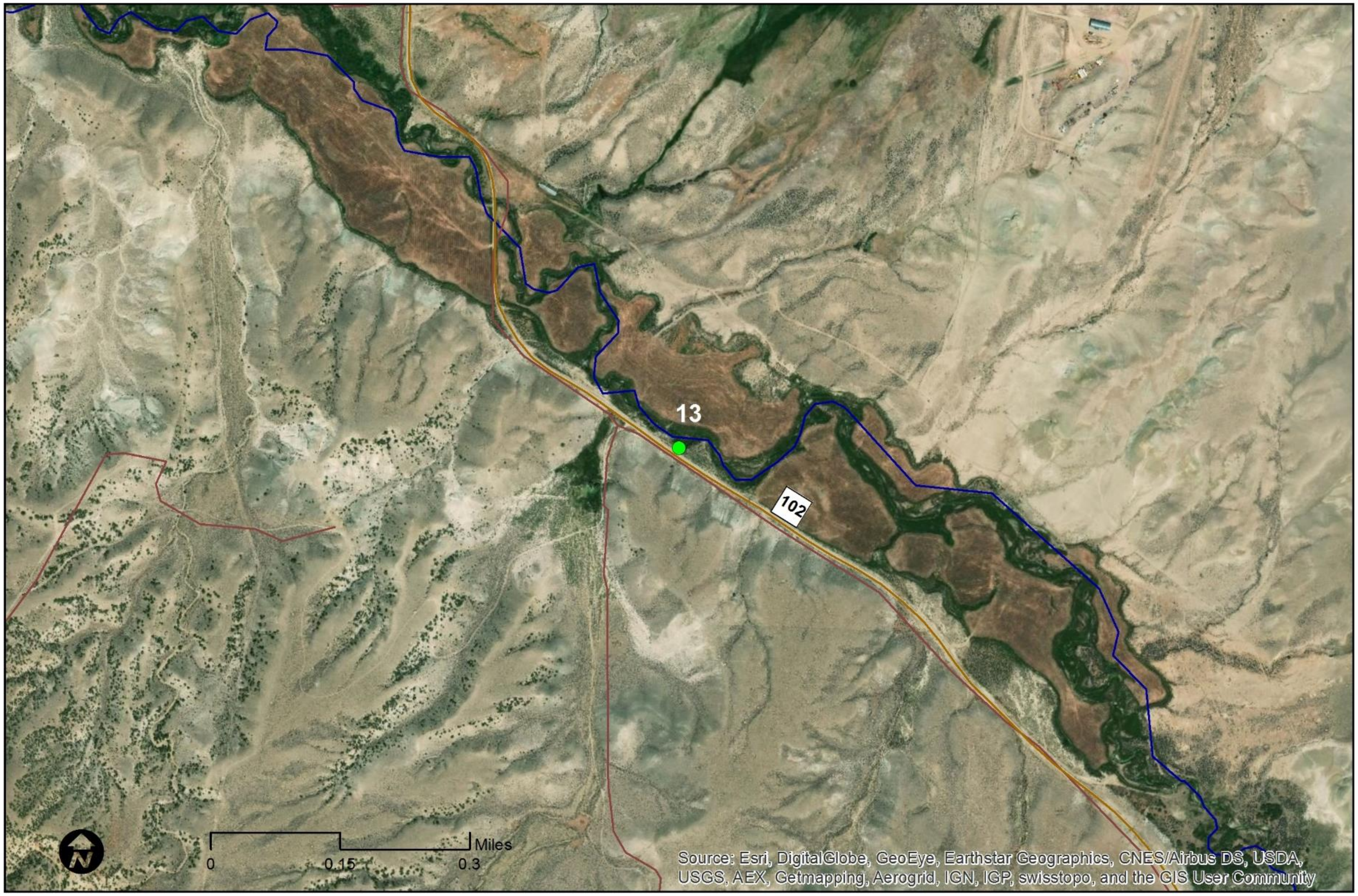


Sampling Sites 9 (Badwater Creek below Alkali Creek), 10 (Alkali Creek near Badwater Creek confluence)

and 11 (Badwater Creek above Sand Draw)



Sampling Site 12 - Badwater Creek above Lost Cabin



Sampling Site 13 - Upper Watershed

Sampling Site 14 - Above Outfalls

Appendix B. SOP: Macroinvertebrate Sampling with Hester-Dendy Artificial Substrates.

A. Scope

This method pertains to the collection of large river (nonwadeable) macroinvertebrate sampling for the calculation of the Large River macroinvertebrate Index of Biotic Integrity (LR-mIBI, Weigel and Dimick 2011). This SOP will cover:

a. Specifications for the Hester-Dendy (HD) artificial substrate samplers
b. Sample deployments
c. Sample retrievals
d. Macroinvertebrate sample preservation
e. Safety
f. LR-mIBI Calculation

B. Summary of Method

Hester-Dendy (HD) artificial substrate samplers were selected as collection devices because they are uniformly applicable in a wide variety of rivers, including habitats where other methods will not work. The samplers are deployed and allowed to colonize for a 6-week duration between June and September. Sampler construction and deployment were based upon Ohio EPA (1987) protocols.

Three HD samplers are fastened to a cinder block are deployed between June and September. HDs should be either set directly on rocky substrate or attached to a snag to maintain 0.75 to 1.5 m of water above the sampler at low flow. Placement directly on fine sediment should be avoided where muck or shifting sand will bury the block and samplers. Sampler placement should be consistent with the recommended minimum velocity of 0.3 ft/sec (Ohio EPA 1987).

After 6 weeks, retrieve the samplers minimizing disturbance hat may dislodge the invertebrates as the samplers are lifted to the surface. Without delay, set the block on the boat deck or shore, then quickly cut the HDs from the block and place the HDs in a large plastic pan. Remove from the pan any remaining rope or zip tie material along with their attached macroinvertebrates. Macroinvertebrates attached to zip ties, rope, cinder block or any material that is not the HD sampler should <u>not</u> be included in the sample. Finally, disassemble the HDs, scrape off the organisms, combine the sample contents, preserve them in ethanol, and deliver to Aquatic Biomonitoring Lab (ABL) at UW-Stevens Point. The ABL has a slightly different identification procedure for LR-mIBI samples where 500 individuals are targeted and often contain more Chironomidae individuals that take more time to identify. Because of this LR-mIBI samples are approximately ~3 times the cost of a wadeable mIBI sample.

1. Standard QA/QC practices

Standard field QAQC procedures may include duplicate samples from a particular site. This would require two deployments in a similar location for an identical period of time. CO staff will notify field staff if any duplicates are required for the Large River Macroinvertebrate baseline monitoring program. As part of Local Needs or Targeted Watershed Assessments field staff may include duplicate samples in their project on an as needed basis.

C. Safety

Safety precautions of a general nature should be recognized. Life jackets should be worn if sampling from a boat or in areas of swift current. Collecting samples in cold weather, especially around cold waterbodies, carries the risk of hypothermia and collecting samples in extremely hot and humid

weather carries the risk of dehydration and heat stroke. Staff must have appropriate CPR training according to the current Bureau wide safety policies.

Secondarily, more dangerous conditions may exist when sampling in nonwadeable rivers. Staff should be trained in boat safety and operation if using one to reach a sampling site. Although the fringes of nonwadeable rivers may be wadeable and appear safe, strong currents and wading hazards may exist. PFDs must be worn if wading in the fringes of nonwadeable rivers and extreme caution should be exercised.

D. Equipment

1) Deployment
   a. 3 Hester-Dendy samplers (http://www.hesterdendy.com/8_plate.htm)
      i. 8 – 3 inch x 3 inch plates of 1/8 inch Masonite hardboard
      ii. 1/8 inch gap on top 3 spaces
      iii. 1/4 inch gap in the middle 3 spaces
      iv. 13/8 inch gap in bottom space
   b. 40 lb cinder block
   c. 3/8 inch by 24 inch length zip ties
   d. Small float and rope twine for sample retrieval (optional)
   e. Plastic coated wire or rope to attach to tree or logs (optional)
   f. GPS, camera
   g. Data sheets
   h. Waders
   i. Gloves
   j. PFD

2) Retrieval
   a. Plastic pan(s)
   b. Plastic putty knife, stiff bristle brush
   c. Scissors, wire snips
   d. Squirt bottle
   e. Large bug jar
   f. 500 micron mesh screen
   g. Ethanol
   h. GPS, camera
   i. Data sheets
   j. Waders
   k. Gloves
   l. PFD

Figure 1. Three Hester-Dendy samplers attached to cinder blocks.

E. General Deployment Procedures

1. Secure the 3 – HD samplers to the 40 lb cinder block (Fig 1). This can be done in advance of the deployment day.
2. Set the HD samplers on rocky substrate or attached to a snag to maintain 0.75 to 1.5 meters of water above the sampler at low flow.
    a. Avoid areas with fine sediment (silt or sand) when possible as shifting substrate can bury HD samplers.
3. Samplers should be placed where a minimum water velocity of 0.3 ft/sec (0.09 m/sec).
    a. In practice this amounts to placing the HD sampler in an area with some flow, i.e. not backwaters.
4. After placing the HD samplers attach optional retrieval gear such as floats, wire attached to logs/trees and/or flagging.
5. Take a GPS reading at deployment location and record all pertinent information on data sheets. Take pictures and/or draw maps of the deployment locations.

F. General Retrieval Procedures

1. Locate the HD deployment location using GPS coordinates, hand drawn maps or by locating flagging/floats. Approach the site from downstream until you locate the exact HD location.
2. Trying to minimize as much disturbance as possible as not to dislodge invertebrates lift the HD samplers to the surface.
3. Quickly set the HD samplers on a stable surface and cut the HD samplers free from the cinder blocks and place them in a large plastic pan.
4. Remove any remaining materials used to attach the HD samplers such as zip ties, twine or rope. Macroinvertebrates attached to these should not be included in the final sample.
5. Disassemble the HD samplers in the plastic pan.
6. Using a plastic putty knife, brush and/or squirt bottle remove all invertebrates and debris from the HD plates.
    a. Small invertebrates may be living in small cases of mud so be sure to remove all debris from plates.
7. Pour the invertebrate/debris/water slurry through a 500 micron mesh (d-frame net or sieve bucket) to remove excess water and silt.
8. Transfer invertebrate and debris into a large, cleaned macroinvertebrate jar.
9. Preserve sample with 70% ethanol on site. Samples should be drained and re-preserved with 70% ethanol 1-2 days after collection to maintain appropriate preservation concentration.
10. Samples should be delivered to UW Stevens Point ABL in the late fall-early winter of the year the sample was collected.
11. The ABL will enter macroinvertebrate data into SWIMS and LR-mIBI will be automatically calculated.
    a. As the LR-mIBI calculator is fairly new in SWIMS staff should be sure correct mIBI is calculated when evaluating the data.

G. Documentation

All data collection information should be tracked in the project in SWIMS and on the Non-wadeable Macroinvertebrate Field Data Report (3200-136), which can be found in the lab slip generator. Lab slips should be turned in to the UW-ABL along with the macroinvertebrate sample. Staff should scan or make photocopies of the macroinvertebrate lab slip for their own records. The UW Stevens Point will enter bug data into SWIMS where the LR-mIBI and component metrics will be calculated and stored. For the Large River Macroinvertebrate project site lists are stored on the Monitoring Activity Sheets (http://intranet.dnr.state.wi.us/int/water/monitoring/regionalaccountability.htm). Staff should record when samples are deployed and retrieved on the Monitoring Activity Sheets.

H. LR-mIBI Calculation

All individuals are identified by the UW Stevens Point ABL to the lowest practical level, usually species. The data are entered into the DNR BugProgram and migrated into SWIMS where the LR-mIBI and component metrics are calculated. The LR-mIBI is based upon 10 macroinvertebrate metrics that represent the assemblage structure, composition and function (Table 1). Qualitative ratings are assigned at 20-point increments where <20=Very Poor, 20-39=Poor, 40-59=Fair, 60-79=Good, and 80-100=Excellent.

Table 1. Taken from Table 3, Weigel and Dimick (2011)). Final IBI metrics and scoring criteria (suffix T=taxa, I=individuals).

Metric	Scoring criteria and rating (points)		
	Poor (0)	Fair (5)	Good (10)
Insect-T	0–21	22–31	>31
Insect-%I	0–89%	90–95%	>95%
EPT-T	0–6	7–15	>15
Dom_3-%I	>66%	41–66%	0–40%
MPTV	>6.440	5.875–6.440	0.000–5.875
$IntolEPT_2$-%I	0%	0.1–3%	>3%
$TolChir_8$-%I	>16.0%	2.5–16.0%	0.0–2.4%
EcoFTN	0–8	9–12	>12
Gath-%I	>54%	16–54%	0–15%
Scr-%I	0.0%	0.1–7.4%	>7.4%

I. References

Ohio EPA (Ohio Environmental Protection Agency). 1987. Biological criteria for the protection of aquatic life. Volume II: users manual for biological field assessment of Ohio surface waters. Ohio Environmental Protection Agency, Columbus, Ohio. (Available from: http://www.epa.state.oh.us/dsw/bioassess/BioCriteriaProtAqLife.aspx).

Weigel, B.M., and J.J. Dimick. 2011. Development, validation, and application of a macroinvertebrate-based index of biotic integrity for nonwadeable rivers of Wisconsin. *Journal of the North American Benthological Society*. 30:665-679.

K. DIY Hester-Dendy Sampler Construction

Each HD sampling costs ~$13 a piece if purchased from http://www.hesterdendy.com/8_plate.htm. HDs can be made in house with minimal equipment using the following specifications. Each sampler consisted of a 4 inch eyebolt with a wingnut that held eight 7.6 × 7.6-cm (3 inch x 3 inch) plates made of 3.2-mm-thick (1/8 inch) masonite hardboard. Spacing between the plates was 3.2 mm (1/8 inch) between each of the first 3 plates, 6.4 mm (1/4 inch) between each of the next 3 plates, and 9.6 mm (3/8 inch) between the last 2 plates.

I have used washers to acquire the appropriate spacing between the hardboard plates, but since washer thickness varies among washers it can be time consuming to get accurate spacing. Others have used ½" square hardboard material for spacers, whereas others use bushings made of biologically inert plastic. Stainless steel hardware does not rust so it is easy to disassemble and reusable. HD samplers are available from several vendors, or you can make them yourself. I estimate one 4' x 8' hardboard sheet, after subtracting for all of the 1/8" saw cuts, yields 56 samplers. Three HD samplers constitute one sampling unit (i.e., for each site, 3 samplers are deployed and the inverts collected from those samplers are combined).

J. SOP updates tracking

Version #	Date	Sections	Name	Approval
1.0	June 2011	All	Weigel	
2.0	03/26/2015	All	Shupryt	Shupryt, 2015

This document is available electronically on the WDNR's website.

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WDNR PUB-WY-080-2015

Appendix C. SOP: Fish Collection Methods

STANDARD OPERATING PROCEDURES FOR FIELD SAMPLERS

VOLUME II
Revision 3.1

BIOLOGICAL AND HABITAT RELATED TECHNIQUES


Rapid Creek below Pactola Reservoir

STATE OF SOUTH DAKOTA
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
WATERSHED PROTECTION PROGRAM

STEVEN M. PIRNER, SECRETARY

JANUARY, 2017

STANDARD OPERATING PROCEDURES
FOR FIELD SAMPLERS

VOLUME II

BIOLOGICAL AND HABITAT SAMPLING

Prepared by The Watershed Protection Team:
(Pete Jahraus, Rich Hanson, Barry McLaury, Sean Kruger, Alan Wittmuss, Robert (Bob) Smith, Paul Lorenzen, Andy Kopp, Jesse Wilkins, Anine Rosse, Kris Dozark, Jeremy Schelhaas, and David Hertle)

STATE OF SOUTH DAKOTA
DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES
WATERSHED PROTECTION PROGRAM

STEVEN M. PIRNER, SECRETARY

Revision 3.1

January, 2017

8.0 FISH COLLECTION METHODS FOR WADEABLE STREAMS IN SOUTH DAKOTA

A bag seine represents the primary fish capture technique used to sample the diverse array of wadeable stream habitats for the purpose of obtaining fish community level information. A backpack electro-shocker is considered a secondary fish collection method when it is not feasible to effectively sample the stream with a bag seine. A backpack shocker is used in streams with significant snags, often higher gradient cobble-boulder dominated streams found in the Black Hills and those along the Prairie Choteau escarpment. The decision to use either collection method is at the discretion of the field crew. Always make sure to obtain the appropriate collection permits (state and federal) prior to fish sampling.
The main objective of most fish sampling efforts is to gain a representative sample of the resident fish assemblage. The standard approach is to make a single pass with either sampling method through the established stream reach. A single pass provides a timely and standardized approach. A single pass is considered sufficient effort to determine precise patterns in fish assemblage, community structure, and function for bioassessment (Bateman et al. 2005, Bertrand et al. 2006). Multiple passes require significant time and would be warranted in situations when the objective is to determine absolute population densities.

Fish community structure and function in prairie stream environments can change spatially and temporally depending on seasonal hydrology. The SD DENR Watershed Protection Program recommends sampling fish in mid to late summer, generally July and August. This index period corresponds to a period when most stream flows are stable and at or near base-flow. The general rule is not to sample fish immediately after major storm events and to avoid sampling when the stream is at or above bank full depth. The following sampling protocols are consistent with techniques used by SD Game, Fish and Parks and the Co-op Research Unit at South Dakota State University.

A. Bag Seine Method

1. Use a standard bag seine with 3/16 inch (4.8 mm) to 1/4 (6.4 mm) inch mesh and 4 feet (1.2 m) to 6 feet (1.8 m) in height depending on depth of the stream. The seine should be wide enough to cover bank to bank in the widest location of the stream reach. If the stream reach has a section wider than the most appropriate seine width, sample the best available habitat in the widest section. Tighten the seine by rolling the net on the poles keeping the lead line on the bottom in narrower sections of the stream. Move the seine in a downstream orientation with stream flow.
2. Prior to starting the seine haul, place a straight seine or block net perpendicular from bank to bank across the stream at the furthest downstream end of the reach.
3. The length of an individual seine haul will depend on bank access, size of the stream reach and abundance of fish or debris (i.e. woody debris, aquatic plants-rocks). The recommendation is to scout out the stream reach prior to seining to determine the best exit points to drag the seine onto the bank. The best exit points are generally associated with the head of a riffle or sand bar on inside bends. Exit the stream as much as possible

in long stream reaches with significant fish and/or debris, (each transect) to minimize fish loss. A continuous seine haul is plausible in small stream reaches (i.e. < 100 meters) with low habitat diversity and fish abundance.

B. Runs/Glides and Pool Habitat

4. The seine haul will require 3 operators minimum to effectively sample the reach. One operator will be placed at each bank to hold a seine pole. Each operator will make sure the lead line is riding firmly on the bottom as the floats skim the surface. Start at the upstream end of the stream reach and move in a downstream orientation with the flow. Move downstream in a rapid fashion making sure the bag portion stays completely extended and does not become inverted. A third operator will move behind the seine to keep it free from snags and moving effectively downstream.

5. When exiting the stream channel one operator holds a seine pole firmly on the bank while the other operator swings the seine to the opposite bank. When both seine operators are on the same bank, each operator will drag the lead line in making sure it stays in constant contact with the bottom of the channel or bank. When the bag becomes visible, pick the bag up and place it in the fish holding basket. Invert the bag rolling fish and other contents into the basket. Process fish at the end of each seine haul if necessary to minimize stress and mortality.
6. When conducting the final seine haul at the end of the reach move the seine along the block net in route to the opposite bank. After the bag has been emptied into the fish basket two people will dislodge and roll the block net to form a small bag. Placing one end of the block net in the fish basket slowly work the remaining length of block net into the fish holding basket to capture fish entangled in the block net.

C. Riffle Habitat

1. The same seining process described for runs/glides and pools can be used for riffle habitat if riffle characteristics provide for fluent operation. When riffle characteristics are not conducive to seine operation due to factors such as shallow depth, high velocity-flow or large firm substrates, use the following seining technique to capture fish.
2. Stretch the seine from bank to bank at a location immediately downstream of the riffle. Have all available field crew members walk the riffle downstream towards the net, kicking and disturbing all interstitial spaces to actively push fish downstream into the net. When the process is complete, one seine operator will keep the seine anchored on the bank while the other seine operator arches the seine across the stream to the opposite bank. Each operator will drag the lead line in making sure it stays in contact with the bottom of the channel or bank. Place the bag into a fish holding basket and empty the contents.

D. Backpack Electro-Shocking Method

1. A back-pack electro-shocker should be used to capture fish when physical characteristics of the stream are not conducive to effective seining. The use of any backpack model developed by a major electro-shocking manufacturer (i.e. Smith-Root, Halltech, E-Fish) is considered acceptable. The SD DENR WPP uses an HT-2000 backpack electro-shocker manufactured by Halltech Aquatic Research Inc. It is important to understand the specifications and operating procedures of any unit prior to engaging in fish sampling. The Operations Manual for the HT-2000 is located at: http://www.halltechaquatic.com/pdfs/HT2000manual.pdf. (Halltech, 2013). Make sure to acquire all recommended safety equipment (non-conductive waders-rubber gloves etc.) prior to operation.
2. A measure of the streams conductivity (µS/cm) is required to calibrate voltage and frequency of the shocker unit, prior to fish sampling. Choose a location upstream or downstream of the established sampling reach to calibrate the unit. The operators will need to adjust the voltage and frequency for the streams conductivity in accordance with specifications described in the Operations Manual (Halltech, 2013) see below. Once the shocker unit is engaged, further adjustment to the voltage and/or frequency may need to be made until optimal fish shocking efficiency is achieved.

a. The **output voltage switch** is located in the middle of the unit on the far right side. The output voltage ranges from 50-950 V in 11 steps (50, 100, 150, 250, 350, 450, 550, 650, 750, 850, 950V).

- 50 to 350 volts is typically used in high conductivity waters, >300 µS/cm (microsiemens).
- 450 to 750 volts work best in moderately conductive waters, 100 to 300 µS/cm (microsiemens).
- 850 and 950 output voltage should typically only be used in low conductivity waters, < 100 µS/cm (microsiemens).

Increasing the output voltage just one step may increase the output peak wattage 100% plus or minus depending on the conductivity on the water and the voltage setting (adapted from the *HT-2000 User's Manual*).

b) The **Frequency [Hz] switch** is located in the middle of the unit on the far left side of the panel. The output frequency is in a range from 5-250 Hz in 11 steps (5, 10, 20, 40, 60, 80, 100, 130, 160, 200, 250Hz). The frequency is best described as the number of times the fish is shocked in a given time period, or the number of pulse waves produced each second. When first shocking a new site start with the lowest frequency setting. Gradually increase the frequency until the desired effect is achieved.

- For example when shocking a water body with a high conductivity, > 300 µS/cm (microsiemens) at an output voltage of 150 volts and a frequency of 60, if you are rolling some fish but feel you aren't getting all of them, try increasing the frequency to 80 or 100 Hz before increasing the voltage to 250 V.

3. During calibration, it is important to make subtle changes to either the voltage or frequency settings to minimize fish mortality. This is especially true in streams with potential to harbor endangered species such as the Topeka Shiner (*Notropis topeka*). In instances where Topeka Shiner presence is detected, immediately move to another location of the stream outside the reach to finish the calibration process. Follow all state and federal permitting guidelines and regulations.

4. Fish shocking should be conducted in an upstream orientation towards a block net positioned at the furthest upstream transect. The fish shocking process will require a minimum of 3 field personnel; one electro-shock operator, a fish netter and someone to trail behind with the fish collection basket. A second fish netter would be ideal if a fourth person is available in the field crew. Before starting the shocking process, document the shocker settings (volts, frequency, battery amps) and reset the timer.
5. A general rule for fish shocking is to cover all available habitats in the stream. In small streams (5-10 meters wide) with low habitat diversity it is possible to cover all available habitats with relative ease. In medium sized streams (10-25 meters), sampling effort should be directed towards those habitats most likely to hold fish such as snags, undercut banks, large cobble-boulders and scour holes along the banks and channel. **Do not focus sampling efforts on one particular habitat**. In larger streams >25 meters wide, sample right and left bank margins and major channel features, alternating between transects. Larger streams may be difficult to sample effectively with a back-pack shocker. Alternate methods such as a barge shocker or boat shocker may be warranted.
6. In very small streams less than 5 meters wide it is relatively easy to cover all habitats rather quickly and efficiently. A minimum of 30 minutes shock time should be spent in very small streams to avoid rushing through the process.
7. The level of shocking effort given to small and medium sized streams greater than 5 meters wide will depend on site-specific characteristics of the stream reach such as; size, navigability and habitat diversity. Field crews should devote sufficient shock time and overall fishing time necessary to thoroughly cover all available habitats required to gain a representative collection of the resident fish assemblage. As a benchmark,

field crews should spend a minimum of 2 hours shock time in streams with average widths of five to twenty-five meters.

8. When finished shocking at the furthest upstream transect make sure to record the shocking time, generally in seconds to quantify level of effort. Process the captured fish as often as possible to minimize stress and mortality.

E. Fish Processing

1. The level of fish processing will depend on individual project goals and objectives. The following stepwise procedures are conducted by the Watershed Protection Program to obtain information required to generate community level metrics, length frequency, and relative species abundance. A full set of datasheets are provided in Appendix F.

   - Start by sorting individual fish species into separate buckets for processing. A list of fish species found in South Dakota is provided in Appendix F, Table F-5 for reference.
   - Identify, measure and record the length (millimeters) of a random selection of at least 50 individual fish of the same species to cover representatives of the most abundant size classes (Appendix F, Table F-1). Measure any large fish not well represented in the collection, in addition to the subset of 50 individual fish.
   - If the number of a particular species is estimated to be less than 100 individuals, physically count the remaining individuals and record the total count on the datasheet (Appendix F, Table F-2).
   - If the total fish count is expected to exceed 100 individuals, bulk weigh the initial subset (n=50) of fish to the nearest gram. Take a

bulk weight of the remaining fish and record on the datasheet (Appendix F, Table F-3).

- For uncommon or unknown fish species, select one to two good fish specimens of each species in the collection to voucher.
- Place voucher specimens in an appropriate container and preserve with 10% formalin.
- Fill out the label information and place the label inside the voucher container. Make sure to use write in the rain paper to print fish voucher labels (Appendix F, Table F-6).
- For each common fish species photo vouchering procedures should be employed and are as follows.
- Chose one high quality representative fish and place it in or on a measuring board and place them on a large white board. On the top right corner of the white board write the project ID, date, stream name, location, species name, and collector initials.
- Using a digital or cell phone camera, take a picture of the fish on the whiteboard making sure to include documentation information in the photo frame. Fill out information and document species photos, common name, photo frame (ID), and comments in the Photo Vouchering Log Datasheet (Appendix F, Table F-4).

When Finished Sampling the Reach/Site, Clean all equipment, boats, shocker wands; and sampling gear including waders, nets, and buckets of debris, dirt and grime with stream or lake water and follow all cleaning procedures outlined in Section 9.0 of SD DENR WPP Standard Operating Protocols, Vol I, (Decontamination Protocols for Equipment and Field Personnel)!!!

SD DENR WPP Fish Data Sheet	**Page: __1___ of _____**

Site ID:	**Stream Name:**	
Date:	**Habitat Sample ID #**	**Pass# _____ of _____**
Gear Type: (circle one) Backpack	Seine (blocknet: Yes or No)	Boat Mounted Shocker
Gear Style: (i.e. Halltech, model #, 3/16 inch, etc)		
Record Shocking Information below		
Water Conductivity (μS/cm):	**Water Temperature** (°C):	**Peak Voltage:**
Peak Amperes:	**Wave Form** (ac, dc or pdc):	**Duration** (sec):

Common Name	Length (mm)	Weight (g)	Disease	Common Name	Length (mm)	Weight (g)	Disease

*Parasites & Anomalies Code: D=deformed, EF=eroded fin, FG=fungus, LE=lesions, AW=anchor worm, BS=black spot, EM=emaciated, O=other

SD DENR WPP Fish Data Sheet **Page:_____ of _____**

Site ID: **Stream Name:** **Date:**

Common Name	Length (mm)	Weight (g)	Disease	Common Name	Length (mm)	Weight (g)	Disease

*Parasites & Anomalies Code: D=deformed, EF=eroded fin, FG=fungus, LE=lesions, AW=anchor worm, BS=black spot, EM=emaciated, O=other

Site ID:	Stream Name:				Date:	
Fish Counts (after first 50, for species with less than 100 total individuals)						
Species Common Name	Count1	Count2	Count3	Count4	Count5	Count Total

Site ID:	Stream Name:			Date:		
Fish Bulk Weights (weights after first 50, for species with more than 100 individuals)						
Species Common Name	Weight1 (g)	Weight2 (g)	Weight3 (g)	Weight4 (g)	Weight5 (g)	Total Weight (g)

Fish Photo Vouchering Log			
Site ID:	Stream Name:		Date:
Count	Species Common Name	Photo frame number (ID)	Comments
1			
2			
3			
4			
5			
6			
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Appendix D. SOP: Establishing and Monitoring Gauge Stations

Aethon Energy Badwater Creek Use Attainability Analysis

Standard Operating Procedures for Establishing and Monitoring Gauge Stations

Gauge stations will be established to continuously record water stage and water temperature at eight pre-selected locations. The table below provides a summary of the anticipated gauge station locations. The gauge sites will be co-located in areas that will be sampled for water quality parameters.

Table 1. Summary of gauge site locations

Site ID	Waterbody	Description	Logger	Latitude	Longitude	Ownership
1	Badwater Creek	Near Bonneville Road	D	43.266567	-108.067206	Two-B Land & Livestock Co, Inc.
3	Badwater Creek	Below Dry Creek	D	43.269110	-107.922680	Picard Livestock Co
5	Badwater Creek	Below Schoening Creek	D, O	43.277170	-107.778470	Gardner Livestock LLC
9	Badwater Creek	Below Alkali Creek	D, *	43.261502	-107.676281	Louisiana Land & Exploration Co
10	Alkali Creek	Alkali Creek terminus	D	43.260150	-107.674670	BLM
11	Badwater Creek	Above Sand Draw	D, *	43.262887	-107.666642	Clear Creek Cattle Co
12	Badwater Creek	Above Lost Cabin	D	43.307830	-107.613270	Louisiana Land & Exploration Co
13	Badwater Creek	Upper Watershed	D, O	43.339730	-107.455370	BLM

Abbreviations: D, pressure transducer and temperature logger; O, barologger
* Existing stilling well and levelogger - no additional install necessary

Gauge Station Installation

Gauge stations will be located in a reach of stream that has characteristics of a stable, uniform channel. The stream channel types in this area are not ideal for placement of gauges because they are largely comprised of very erodible, unstable soils; however, the best possible locations will be selected during site reconnaissance activities. Gauge stations will be constructed in a location that minimizes the potential for destruction during high flow events or by ice and debris movement.

Each gauge station will consist of a stilling well, a data logger, and a temporary benchmark (TBM). The stilling well will be a 2-inch diameter galvanized pipe with a conical point and vertical slots or holes. The vertical slots or holes will be placed at the bottom of the well to allow for equilibrium between the water height in the well and the water height in the stream. The stilling well will be driven into the bed of the stream channel next to an accessible bank using a manual fence post driver (see Figure 1 for typical stilling well installation).

FIGURE 1 – TYPICAL STILLING WELL INSTALLATION

Once the stilling well has been installed, a TBM located outside of any potential bank erosion will be installed near each gauge station. Each TBM will consist of an 18-inch long piece of ½-inch diameter rebar driven into the ground and marked with flagging and lath for future locating. An assumed elevation of 100.00 feet will be assigned to each TBM at each site. A level survey using a transit level will be performed relative to the TBM elevation. The elevation of the stilling well cap lip, channel bed at the thalweg, water surface elevation (WSE) at the well, and point of zero flow (PZF) will be measured and recorded in the project specific field book. These measurements will be used to ensure the data logger sensor is located vertically below the PZF and thus remains submerged during lower flows.

Solinst 3001 LT Levelogger Edge data loggers will be deployed in each stilling well per manufacturer's specifications and the Solinst Levelogger Series User Guide (User Guide), included in the attachments. Any required calibration and initialization will be performed prior to field deployment per manufacturer's specifications and the User Guide. The data loggers will be installed with Solinst direct read cable assemblies and well cap assemblies. This assembly allows for downloading data without removing the data logger from the stilling well. The data loggers will be placed in the stilling well so that the sensor is at or below the PZF. In addition, the data loggers will be placed inside of two elongated silicon, rubber or latex balloons filled with non-toxic, non-corrosive anti-freeze solution. The balloons will be sealed to contain anti-freeze and prevent water from entering balloon, following directions in Section 10.1.5.1 of the User Guide.

Installers will record the total well depth (from well cap lip to bottom of well), distance from the well cap lip to the data logger sensor, and distance from well cap lip to PZF. Measuring the elevation difference between the TBM and well cap lip in the future can be used to determine if the stilling well shifts or jacks (freeze-thaw) during the life of the project. In addition, a waypoint shall be collected and recorded at each stilling well location and TBM using a handheld GPS for locating the site during future monitoring events.

The data logger will be initialized and set to record measurements of water temperature (°C) and water level (feet) at 1-hour intervals, at the top of the hour, following the manufacturer's instructions. Data logger clocks should be set to local time and synchronized to world clock time for Denver at https://www.timeanddate.com/worldclock/usa/denver. To synchronize the data logger clock, set the laptop clock in-synch with the time displayed on the website. The data logger clock can then be easily synched to the laptop clock when connected via the PC interface cable (see Section 5.4 of the User Guide).

Installation of two Solinst 3001 LT Barologger Edge data loggers will also be necessary to barometrically compensate the Levelogger readings. Each Barologger can be used to compensate the Leveloggers in a 20 mile radius and/or within 1,000 feet of change in elevation. To account for this, a Barologger will be installed at both Site 5 and Site 13 in dry areas above high water per Section 10.1.3 of the Levelogger Series User Guide, attached as Appendix A. The Barologger at Site 5 will be used to compensate the Leveloggers at Sites 1-12, and the Barologger at Site 13 will be used to compensate the Levelogger at Site 13 only. The Barologgers will also be synchronized to the computer (as described above) and set to record measurements at 1-hour intervals, at the top of the hour, following the manufacturer's instructions. The Barologgers will be installed in dry wells with vented Solinst well cap assemblies similar to the stilling wells, but without the vertical slots or holes.

Gauge Station Data Collection

Gauge station data will be collected at the beginning of the project (initial) and on a monthly basis. Data will be collected, stored and analyzed by Aethon and/or their contractors. During the initial gauge installation and during each subsequent sampling event, the following protocol will be performed to ensure proper collection of gauge data.

1. Upon arrival at the site, record the site name, date, time, weather conditions and data collectors' name in the project specific field book.
2. Upon arrival at the site, take photos of the stilling well capturing the condition of the well and well cap assembly. Also, take necessary photos to document any debris or matter that may have obstructed normal operation of the stilling well. Record the photo numbers and corresponding descriptions in the project specific field book.
3. Using a transit level, survey the elevation difference between the TBM and well cap lip and record the result (to the nearest hundredth of a foot) in the project specific field book. This measurement can be compared to the previous month's elevation to determine if the stilling well has shifted vertically since the last data collection event. In addition, measure the distance from the well cap lip to the water surface beside the stilling well with a metal tape measure and record the distance and corresponding assumed WSE (to the nearest hundredth of a foot) in the project specific field book.
4. Download the data from the data loggers to a laptop computer using the Solinst Levelogger PC software and Solinst PC interface cable in accordance with Section 7 of the User Guide. When downloading data, select "All Data" from the Data Control tab (see Section 7.1.2 of the User Guide). If at Site 5 or Site 13, be sure to also collect the data from the Barologger. The raw data files will be named using the following convention "Badwater Creek UAA_Gauge Site Number_Collection Date.xle". For example:
    a. If data is being collected from the <u>Levelogger</u> at Site 5 on August 4, 2019 then the raw data file will be named: Badwater Creek UAA_Site5_LEVEL_04-AUG-2019.xle
    b. If data is being collected from the <u>Barologger</u> at Site 5 on August 4, 2019 then the raw data file will be named: Badwater Creek UAA_Site5_BARO_04-AUG-2019.xle
5. Record the time of data retrieval and location of data file stored on the laptop in the project specific field book.
6. Once data has been downloaded, clear the data logger and set it to begin collecting new data using the Future Start function in accordance with Section 5.8 of the User Guide. The Future Start date and time should be set to begin collecting data at the next upcoming top of the hour (i.e. – if it is currently "10:45:00 AM" then set the Future Start time to "11:00:00 AM"). This will allow for easier correlation of the Leveloggers and Barologgers data.
7. Measure the total well depth with a metal tape measure to ensure the stilling well has not filled with silt or debris and the data logger is suspended freely in water below the PZF. This depth should be compared to the initial installation total well depth. If the data logger is not suspended freely in the well, see Step 8b below for clearing instructions.
8. Inspect the condition of the gauge station and data logger assemblies during each site visit. Record the condition of the gauge station (and description of any adjustments or repairs, if necessary) in the project specific field book.
    a. If it appears the stilling well or dry well has been damaged or misplaced vertically then it will be surveyed relative to the TBM using the transit level. If it is severely damaged, it may need to be re-installed and re-surveyed relative to the TBM and following the process

described in this SOP. The condition of the gauge station and representative photos will be described in the project specific field book.

b. If the stilling well has become silted and/or the data logger is not suspended freely in the well, the data logger should be pulled and the well cleared. This can be done by adding water to the well and purging with a simple well bailer. This process may need to be repeated several times depending on the amount of silt in the well. Once the stilling well is cleared, the total depth should be checked with the measuring tape and recorded in the field book along with the distance from the well cap lip to the data logger sensor.

c. If the balloon has been damaged or anti-freeze has been depleted, a new balloon and anti-freeze assembly should be replaced prior to re-deployment.

d. Maintenance of the data logger shall be conducted in accordance with Section 10.2 of the User Guide.

9. Re-deploy the data logger in the stilling well making sure it has been reset and is recording data per this SOP and the User Guide. Record the time of re-deployment in the project specific field book.

10. While on site, measure instantaneous stream discharge using an appropriate flow meter and subsection measurements along a stream cross section (see Wyoming Department of Environmental Quality, Water Quality Division, Watershed Protection Program, Standard Operating Procedure: *Stream Discharge - Wadeable Streams and Rivers*). Discharge measurements will be used to develop a rating curve and therefore require a range of measurements. If high flows prevent safe entry into the stream, a cross sectional survey of the site may be needed in order to generate 'indirect' discharge measurements.

Time-Lapse Camera Setup and Data Collection

Each gauge station site will be equipped with a time-lapse camera to record the presence of water in the respective channel reach. Brinno TLC 200 Pro cameras in weather resistant housings will be attached to t-posts (or other support structure) near each gauge site (see Figure 2). The cameras will be secured to the support structure and affixed with small locks to deter tampering. The cameras will be mounted to avoid direct sun glare in the lens while still allowing a full view of the channel cross section.

Following the manufacturer's instructions, the cameras will be initialized with the following settings:

1. Time Interval: 1 hour
2. Time Lapse Frame Rate: 5 Frames Per Second (FPS)
3. White Balance Mode: Auto
4. Image Quality: Best
5. Scene: Daylight
6. Timer: 00:00 – 00:00
7. High Definition Range (HDR): Medium
8. Exposure: middle position (- . . . | . . . +)
9. Custom Image: middle position for Saturation, Contrast and Sharpness (- . . . | . . . +)
10. Time Stamp: On
11. Low Light Recording: On
12. Set Date & Time: set to current date and time
13. LED Indicator: Off
14. Band Filter: None

Following the manufacturer's instructions, data will be downloaded from each camera's SD card onto a laptop computer during each monthly monitoring event. The following procedures should be followed to download data and reset cameras:

1. Stop recording and prepare recorded video by pressing and HOLDING the "OK" button until the LCD light turns on and shows the text "Processing". When completed with the processing, it will display the text "Ready".
2. Turn the camera off, remove the SD card from the camera and insert into laptop.
3. Download the data onto the laptop and rename with the download date and appropriate site (EG: *05-FEB-2019 Site 1.AVI*).
4. Check the video on the laptop before leaving the site. Make any necessary changes to the camera or camera angle as needed.
5. Once successfully downloaded and saved to the computer, clear the data from the SD card and re-install in camera.
6. Check battery level and replace batteries (4 AA Energizer Ultimate Lithium batteries) if necessary.

7. Turn camera on and begin recording by depressing the OK button once to get to the preview screen which will read “READY”. Press and hold the OK button again until it shows REC at the bottom bar.
8. Insert camera back into the protective housing and fasten to the support structure ensuring proper orientation to capture full channel cross section.
9. Record the site name, data collectors’ name, date & time of data download, time of camera re-set, name of AVI file and any pertinent observations in the project specific field book.

FIGURE 2 – BRINNO TLC 200 PRO IN WEATHER RESISTANT HOUSING

Attachments

- Solinst Levelogger Series Model 3001 Data Sheet
- Solinst Levelogger Series Model 3001 Deployment Sheet
- Solinst Levelogger Series User Guide
- Brinno TLC 200 Pro User Manual